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(54) Methods and apparatus for reducing cochannel interference in a mixed-rate communication system

(57) A method and apparatus for increasing system capacity in a mixed-rate wireless communication are disclosed. Improvements are obtained using multiuser detection or antenna array processing techniques or both to explicitly cancel or attenuate only the high power users. Multiuser detection may be combined with antenna array processing to recover capacity appropriated by the high-power users. By mitigating the interference effects of only the high-powered users, the computational burden is manageable. An antenna array algorithm or a multiuser detection algorithm or both, are applied only to n high rate users ($n < k$ total users). In an antenna array processing implementation, fewer antennas may be employed (one for each high-rate user). In a multiuser detection implementation, fewer cancellation stages may be employed (one for each high-rate user).

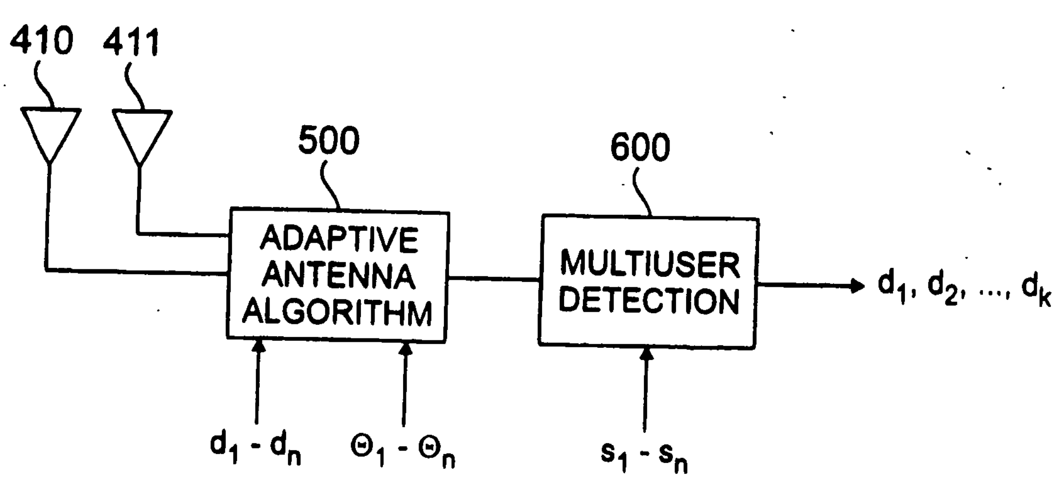

FIG. 4

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Brief Description of the Drawings

[0010]

FIG. 1 is a block diagram of a space-time multiuser receiver in a conventional single-rate wireless communication system;

FIG. 2 is a schematic block diagram of an illustrative conventional antenna array processor of Fig. 1;

FIG. 3 is a schematic block diagram of an illustrative conventional multiuser detector of Fig. 1;

FIG. 4 is a block diagram of a receiver in a wireless communication system in accordance with the present invention;

FIG. 5 is a schematic block diagram of an illustrative antenna array processor that attenuates only high-rate users in the space domain in accordance with the present invention;

FIG. 6 is a schematic block diagram of an illustrative multiuser detector that attenuates only high-rate users in the time domain in accordance with the present invention; and

FIG. 7 is a schematic block diagram of an illustrative wireless receiver that attenuates only high-rate users in both the space and time domains in accordance with the present invention.

Detailed Description

[0011] The present invention relates to a method and apparatus for mitigating the negative effects that high-rate users have on each other and on all other users in a mixed-rate CDMA system. FIG. 1, discussed below, shows a conventional single-rate multiuser receiver 100 that uses antenna array processing 200 and multiuser detection 300 to cancel the effects of each user. The present invention utilizes an antenna array algorithm or a multiuser detection algorithm or both to efficiently recover capacity appropriated by only the high-power users. In accordance with a feature of the present invention, the antenna array algorithm (FIG. 5) or the multiuser detection algorithm (FIG. 6) or both (FIG. 7), are applied only to the *n* high rate users.

ANTENNA ARRAY PROCESSING

[0012] As shown in FIG. 1, signals from multiple antennas 110-112 are combined in a conventional manner using an adaptive antenna array algorithm 200 to mitigate interference in the spatial dimension. As previously indicated, antenna array processing techniques mitigate the effects of different users by compensating for phase and delay effects. A number of antenna array processing techniques have been proposed or suggested for CDMA systems by both the academic and commercial communities. One illustrative implementation of an antenna array processor 200 is shown in FIG. 2. The adaptive antenna array algorithm 200, for example, may make use of training sequences (d_l through d_k) or directions of arrival (θ_l through θ_k) for all the users, in a known manner. Generally, as shown in FIG. 2, antenna array processing techniques utilize a linear combination of the signals received by each antenna 110-112, weighted using a complex weighting coefficient (w_l through w_k), to point each antenna at a specific user and thereby cancel out all other users. Assuming the directions of arrival (θ_l through θ_k) for each of the interfering sources, s, are known, then a matrix of their spatial signatures may be found:

$$A = [s(\theta_1), s(\theta_2), \ldots s(\theta_k)]$$

Then, by defining a unit vector, e_1, the zero-forcing weights are obtained in a known manner by:

$$w^H = e_1{}^T A^H (AA^H)^{-1}.$$

Thus, to implement the zero-forcing algorithm, w_k must be computed, and the complexity of the computation depends on the number of antennas. In addition, the number of antennas depends on the number of sources to be cancelled. For a more detailed discussion of adaptive antenna array processing, see, for example, Lal Godara, Application of Antenna Arrays to Mobile Communications, Part II: Beam Forming and Direction-of-Arrival Considerations, Proc. of IEEE, Vol. 85, No. 8 (Aug. 1997), incorporated by reference herein.

MULTIUSER DETECTION

[0013] The conventional receiver 100 of FIG. 1 also includes a multiuser detection algorithm 300 to cancel interference in the time domain. Multiuser detection techniques recognize that each user has a characteristic shape (or spreading code), s_l through s_k, that is known to the base station. One implementation of a multiuser detection technique, known as a successive interference canceller 300, is shown in FIG. 3. A conventional successive interference canceller 300 contains a detect/regenerate/subtract (DRS) unit 310 in series for each of *k* users, and an ordering controller 320. A successive interference canceller 300 estimates the signal, d_n, for a single user and then subtracts the estimated signal, d_n, from the remaining signal. The signal estimate, d_n, is obtained using a matched filter corresponding to the users' characteristic shape. Thus, for a user corresponding to the final stage, a clear signal is obtained because the interference of all prior users has

rate user and then subtracts the estimated signal, d_n, from the remaining signal. The signal estimate, d_n, is obtained using a matched filter corresponding to the high-rate users' characteristic shape, s_1 through s_n. The ordering controller 730 orders the high rate users by power level, and then successively removes each n high rate user from the highest to lowest power levels. Lower rate voice users are detected by ordinary matched filters 740-742 with the multiple antenna signals combined via MRC, or some other technique.

[0020] It is to be understood that the embodiments and variations shown and described herein are merely illustrative of the principles of this invention and that various modifications may be implemented by those skilled in the art without departing from the scope of the invention.

Claims

1. A method of receiving a signal in a mixed-rate communication system, said communication system having at least one high-rate user and a plurality of low-rate users, said method including a step of reducing interference effects:
   CHARACTERISED IN THAT
   said reducing step reduces the interference effects of said at least one high-rate user only.

2. The method according to claim 1, wherein said reducing step comprises the step of applying a multiuser detection technique only for said at least one high-rate user.

3. The method according to claim 2, wherein said multiuser detection technique uses a successive interference canceller (SIC).

4. The method according to any of the preceding claims wherein said reducing step comprises the step of applying an antenna array processing technique only for said at least one high-rate user.

5. The method according to any of the preceding claims, wherein said at least one high-rate user is a data user.

6. The method according to any of the preceding claims, wherein said low-rate users are voice users.

7. The method according to any of the preceding claims, wherein said reducing step produces a remaining signal that reduces the interference effects of said at least one high-rate user and said method further comprising the step of decoding said remaining signal for said low-rate users.

8. The method according to claim 7, wherein said decoding step uses a matched filter detector.

9. A receiver for receiving a signal in a mixed-rate communication system, said communication system having at least one high-rate user and a plurality of low-rate users said receiver comprising means arranged to carry out a method as claimed in any of the preceding claims.

10. A method for receiving a signal in a mixed-rate communication system, said communication system having at least one high-power user and a plurality of low-power users, said method including a step of reducing interference effects:
    CHARACTERISED IN THAT
    said reducing step reduces the interference effects for said at least one high-power user only.

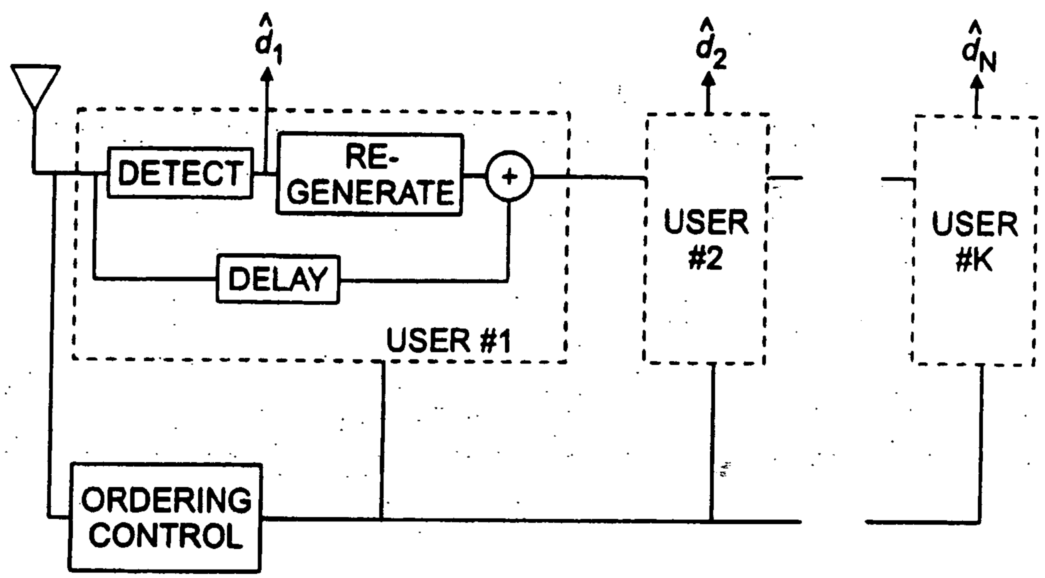

FIG. 3
PRIOR ART

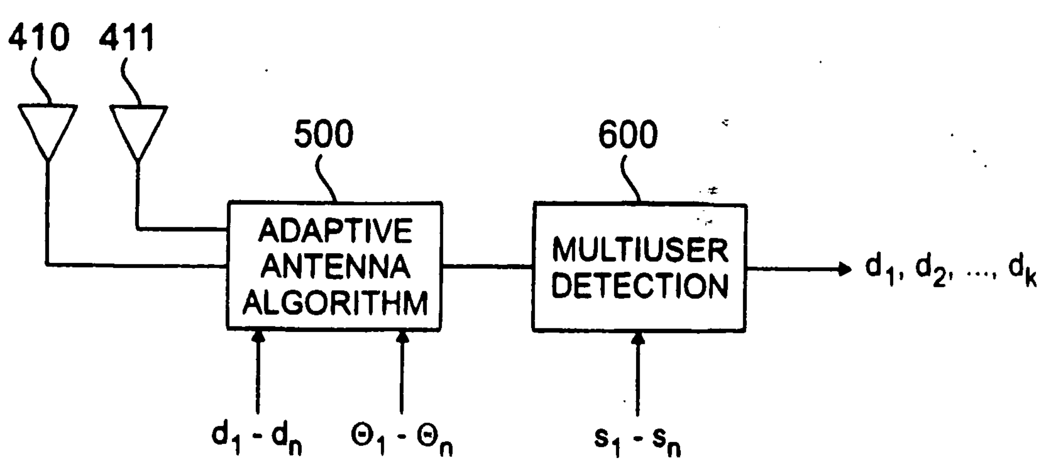

FIG. 4

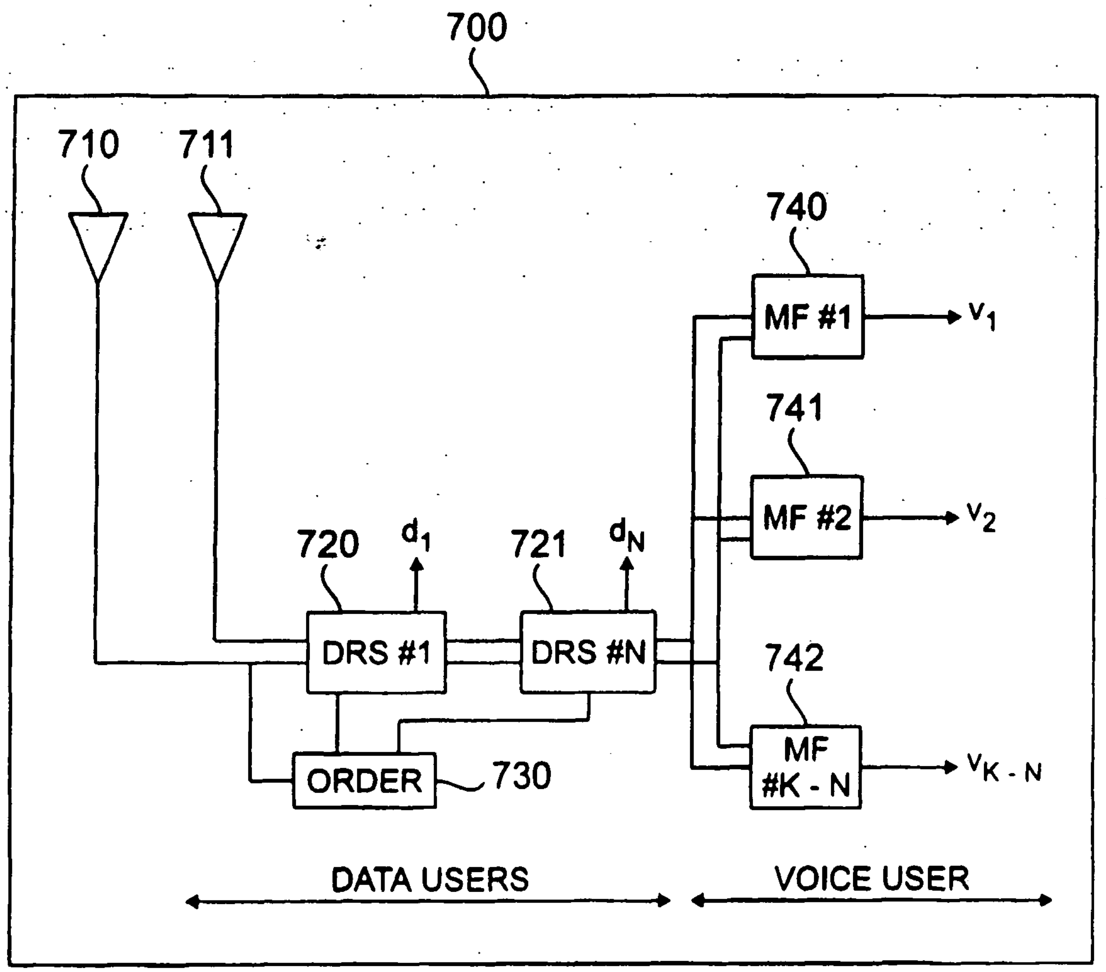
700
710
711
740
MF #1
v_1
741
MF #2
v_2
720
d_1
721
d_N
DRS #1
DRS #N
742
MF #K - N
v_{K-N}
ORDER
730
DATA USERS
VOICE USER

FIG. 7